

*POSITIVE CONDITIONED SUPPRESSION: AN
EXPLANATION IN TERMS OF MULTIPLE
AND CONCURRENT SCHEDULES¹*

D. A. STUBBS, J. E. HUGHES, AND S. L. COHEN

UNIVERSITY OF MAINE, ORONO, MACALESTER COLLEGE,
AND BLOOMSBURG STATE COLLEGE

Rats performed under a baseline variable-interval schedule of food presentation. A response-independent food schedule was then superimposed on the baseline schedule for different periods of time across different conditions. The response-independent schedule operated for the whole session in some conditions, intermittently for sixty second periods in some, and intermittently for ten-second periods in others. Under these latter two sets of conditions, the response-independent food schedule was stimulus correlated and alternated with the baseline schedule according to a multiple schedule. Response-independent food presentations always suppressed responding. The degree of suppression tended to increase the longer the period of response-independent food. Control conditions, in which the superimposed schedule was response-dependent, rather than response-independent, did not produce response suppression. The results fit an analysis of positive conditioned suppression phenomena in the context of multiple and concurrent schedule effects.

Key words: positive conditioned suppression, multiple schedule, concurrent schedule, response-independent food, operant-respondent interaction, contrast, autoshaping, rats

If stimulus-shock pairings are intermittently superimposed on an operant schedule, response rate typically is suppressed in the presence of the stimulus. This procedure is the traditional conditioned anxiety or conditioned-suppression procedure (Blackman, 1977; Lyon, 1968; Millenson and de Villiers, 1972). Azrin and Hake (1969) demonstrated that a stimulus terminating with a response-independent positive reinforcer also produces response suppression. For example, a tone ending with response-independent food reduced responding maintained by a schedule of food presentation. These results demonstrated that positive reinforcers may function like aversive stimuli, leading to the term positive conditioned suppression.

The similarity of the positive and negative conditioned suppression procedures, both in terms of method and outcome, has led many authors to place the results within the context of two-process learning (Rescorla and Solomon, 1967) and to emphasize the interactions of operant and respondent processes (Azrin and Hake, 1969; Hake and Powell, 1970;

Meltzer and Brahlek, 1970; Miczek and Grossman, 1971; Van Dyne, 1971). The positive conditioned suppression experiment may be viewed as involving an operant procedure (the baseline schedule) on which a respondent procedure is superimposed; the stimulus may be viewed as a conditioned stimulus (CS) paired with an unconditioned stimulus (US), the response-independent reinforcer.

The two-process learning framework has provided a basis for discussions of positive conditioned suppression. For example, the duration of a CS is an important variable in respondent-conditioning procedures and has also been studied in positive conditioned suppression research (Meltzer and Brahlek, 1970; Miczek and Grossman, 1971; Smith, 1974). Variation in the duration of the stimulus (CS) paired with the response-independent reinforcer (US) has yielded results compatible with a respondent-conditioning interpretation by showing a greater degree of response suppression as the duration of the stimulus was decreased (see, however, Smith, 1974, as well as Kelly, 1973, for qualifying factors).

Although the two-process learning view provides a context for conceptualizing the positive conditioned suppression results, there may be some value in considering the suppression research within a different context, that

¹Portions of the paper were presented at the Eastern Psychological Association meeting in Washington, D.C., in 1973. Reprints may be obtained from D. A. Stubbs, Department of Psychology, University of Maine, Orono, Maine 04473.

of multiple and concurrent schedules. This context is not incompatible with a two-process learning position (*e.g.*, Rachlin, 1973; Schwartz and Gamzu, 1977) but it does suggest a somewhat different view of positive conditioned suppression phenomena.

The positive conditioned suppression procedure has features similar to multiple and concurrent schedules. Multiple schedules contain two or more component schedules, each associated with its own stimulus. The suppression procedure may be viewed as a multiple schedule with two components. In one component, responses are reinforced according to one schedule (*e.g.*, a variable-interval 60 sec schedule). In the second (CS) component, a different stimulus and schedule arrangement are in effect; the baseline schedule continues to operate, but additionally, a response-independent reinforcer is delivered at the end of the component. The arrangement in this second component involves concurrent scheduling of reinforcers, some according to a response-dependent schedule and some according to a response-independent schedule. In many ways, the reinforcement arrangement in the second component resembles one that has been used in concurrent schedules (Rachlin and Baum, 1972). Concurrent schedules involve two or more schedules that operate simultaneously (Catania, 1966; de Villiers, 1977). Typically, a separate response is required for each schedule; however, an alternate arrangement involves reinforcement of responses under one schedule while reinforcers are concurrently delivered independently of responding according to a second schedule. Research using schedules of this variety has shown that responding is reduced by presentation of response-independent food (Catania, 1973; Edward, Peek, and Wolfe, 1970; Rachlin and Baum, 1972; Zeiler, 1976). Rachlin and Baum, for example, reinforced pigeons' responses according to a variable-interval schedule. Then, food was concurrently presented according to a response-independent schedule (a variable-time schedule). Response-independent food presentation lowered response rate; response rate decreased as the rate or amount of response-independent food increased. The CS component of the suppression procedure is very much like a concurrent schedule in which food is presented both for and independently of responses. The major procedural

difference is that the concurrent aspects of the suppression procedure take place in a multiple schedule. Perhaps the suppression observed in a positive conditioned suppression procedure results from the delivery of a response-independent reinforcer concurrent with a response-dependent schedule.

Placing the suppression literature in the context of concurrent and multiple schedules has implications for the way we view the literature. Some implications of this context formed the basis for the present experiment.

Past suppression research has suggested a greater degree of response suppression with shorter-duration CSs (Meltzer and Brahlek, 1970; Miczek and Grossman, 1971). These findings are, however, confounded by the fact that differences in CS duration are accompanied by differences in the relative rate of response-independent reinforcement. Consider the following arbitrary values: a baseline VI 60-sec schedule, and CS durations of 10, 30, and 60 sec. With the 10-sec CS, there would be one response-independent reinforcer each CS period but a response-dependent reinforcer each sixth period, on average (due to the VI 60-sec schedule). Thus, there is a ratio of six response-independent reinforcers to one response-dependent reinforcer. With the 30-sec CS there would be a ratio of two to one and with the 60-sec CS, a ratio of one to one. Therefore, shorter CS durations provide a greater relative rate of response-independent reinforcement within the CS component. Rachlin and Baum (1972) found greater suppression of concurrent performance as the rate of response-independent food increased. Their results are compatible with results on CS duration previously presented in the context of the two-factor theory. However, their data suggest that relative reinforcement rate is more important than CS duration in producing suppression. Perhaps varying the duration of the concurrent component (CS duration) might have a small or negligible effect as long as the ratio of response-dependent to response-independent reinforcers was held constant. The concurrent component (CS) could last 10 sec, 60 sec, or even the whole session; however, during the component, response-independent reinforcers could be delivered every 10 sec. Thus, the ratio of response-dependent to response-independent reinforcers would be held constant. Similar effects on response rates,

whether the concurrent component lasted 10 sec, 60 sec, or the whole session, would indicate that the relative rate of response-dependent and response-independent reinforcement was a more important variable than the CS duration. The present experiment was designed to provide information on this question.

METHOD

Subjects

Six albino rats, from the University of Maine colony, were experimentally naive and approximately 90 days old at the start of the experiment. Subjects 1 to 3 were males and 4 to 6 were females. The rats were approximately 23-hr food deprived at the start of each session.

Apparatus

The experimental space was a standard two-lever rat chamber with feeder between the levers. The left lever was used, the right lever was removed. A "Jewel" lamp was located the lever, and a second light was located above the chamber. An auditory stimulus was presented by a Sonalert. Reinforcers were 45-mg Noyes pellets. The experimental space was housed in a Scientific Prototype enclosure, Model SPC-300, located in a darkened room with white noise. Sessions were arranged by relay circuitry located in an adjacent room.

Procedure

Sessions, conducted daily, lasted approximately 60 min or until 100 food pellets were delivered, whichever came first. Each condition remained in effect until performance was stable, as judged visually, for at least five sessions.

There were five phases to the experiment. Under each phase, three conditions generally were arranged. (1) Under Baseline, a VI 60-sec schedule was in effect; the schedule contained 17 intervals drawn from an arithmetic sequence (Catania and Reynolds, 1968). Food presentation was accompanied only by the sound of the feeder. (2) Under the Concurrent schedule, response-independent delivery of food was superimposed on, and thus occurred concurrently with, the VI 60-sec schedule. Therefore, some pellets were produced according to the variable-interval schedule, some were delivered independently of behavior. Response-independent food was delivered every

10 sec for Rats 1 to 3; thus, a fixed-time schedule (FT 10-sec) (Zeiler, 1968). Response-independent food was delivered at variable times for Rats 4 to 6 with an average of once every 10 sec; this was a variable-time schedule (VT 10-sec). The variable-time schedule was arranged by a 33-position stepping switch with food occurring in 5-, 10-, or 15-sec intervals. (3) Under the Conjoint schedule, response-dependent schedules were superimposed on the baseline VI 60-sec schedule (Catania, Deegan, and Cook, 1966). The conditions and schedules were just like those of the concurrent, except that here, lever presses produced food according to the VI 60-sec schedule while conjointly producing food according to superimposed schedules. This condition was a control for the concurrent schedule to determine whether the high rates of food delivery might lower response rate due to satiation. The superimposed schedule was fixed-interval (FI) 10-sec for Rats 1 to 3, and a variable-interval (VI) schedule (the first response after 5, 10, or 15 sec produced food) for Rats 4 to 6.

Performance under the three basic conditions—Baseline, Concurrent, and Conjoint—was assessed across five phases of the experiment. These differed regarding (1) the amount of session time the concurrent or conjoint schedules were present, and (2) the amount of response-independent food delivered. Concurrent (or conjoint) schedules were in effect for the whole session (Phase 1), for 60-sec periods (Phases 2 and 5), or for 10-sec periods (Phases 3 and 4). The reinforcer delivered by the response-independent schedules (and also the conjoint control schedules) was one pellet (Phases 1 to 3) or five pellets (Phases 4 and 5). Table 1 shows the different phases of the experiment, the conditions of each phase, and the number of sessions under each. Conditions were in effect for the whole session in Phase 1. The light above the lever was on for the entire session.

A multiple-schedule procedure was used for all other phases, when concurrent and conjoint schedules were presented for 60-sec or 10-sec periods. In one component, signalled by the light above the lever, the VI 60-sec schedule was in effect. In the second component, signalled by a houselight and tone (lever light off), the variable-interval schedule remained in effect, but "extra" reinforcers were sched-

Table 1

Summary of experimental conditions in order of occurrence.

<i>Number of Sessions</i>	<i>Component Duration*</i>	<i>Response-Independent Reinforcer (Control)</i>	<i>Schedule</i>
PHASE 1			
34	Whole Session	—	Baseline
17	Whole Session	1 pellet	Concurrent
10	Whole Session	—	Baseline
15	Whole Session	1 pellet	Conjoint
6	Whole Session	—	Baseline
PHASE 2			
8	60 sec	—	Baseline
14	60 sec	1 pellet	Concurrent
6	60 sec	—	Baseline
16	60 sec	1 pellet	Conjoint
PHASE 3			
11	10 sec	—	Baseline
24	10 sec	1 pellet	Concurrent
PHASE 4			
12	10 sec	—	Baseline
14	10 sec	5 pellets	Concurrent
14	10 sec	—	Baseline
12	10 sec	5 pellets	Conjoint
PHASE 5			
13	60 sec	—	Baseline
10	60 sec	5 pellets	Concurrent
8	60 sec	—	Baseline
13	60 sec	5 pellets	Conjoint

*Note: Component Duration refers to the duration of the component in which concurrent and conjoint schedules operated.

uled during this component in some conditions. Under Baseline conditions, only the 60-sec schedule operated in the houselight-tone component. Under concurrent conditions, response-independent reinforcers were also scheduled (an FT 10-sec schedule for Rats 1 to 3 and VT 10-sec schedule for Rats 4 to 6). Under Conjoint conditions, the FI 10-sec (Rats 1 to 3) or VT 10-sec (Rats 4 to 6) schedules operated in addition to the VI 60-sec schedule. The houselight-tone occurred irregularly on the average of once every 6 min.

When Concurrent or Conjoint conditions were in effect, either for 60-sec periods or for the whole session, these schedules resulted in food delivery throughout the 60-sec period or the whole session. When, however, these conditions were in effect for 10-sec periods, a special problem arose for Rats 1 to 3. For these rats, the schedule value for response-independent food was 10 sec, as it was for

the control conditions. These values were chosen so that food would occur at the end of the component, thus making the procedure the same as a typical positive conditioned suppression procedure. However, use of a component value and schedule values of 10 sec meant that food was delivered just as the stimulus changed from the houselight-tone to the lever light. Further, under the control condition, where a fixed-interval 10-sec schedule was used, the schedule requirement was met at the moment the component terminated. Two procedural adjustments were made to deal with these problems. First, the component stimuli remained on for 1 sec after the delivery of food so that food delivery and component change were not simultaneous. Second, under the control condition, the component remained on until the fixed-interval schedule requirement was met, a response produced food, and then for the additional 1-sec period. In essence, these modifications produced component durations closer to 11 or 12 sec, rather than 10 sec.

The reinforcer assigned by the VI 60-sec schedule was always one pellet; reinforcers assigned by the other schedules were one pellet in the first three phases and five pellets in the last two. The feeder simply operated once when the reinforcer was one pellet but five times in succession when the reinforcer was five pellets.

Generally, the order of conditions was Baseline, Concurrent, Baseline, Conjoint in the different phases. There were, however, two exceptions. One additional Baseline condition was employed at the end of the first phase, since a within-session comparison of performance was not possible as in the case of the multiple schedules. Under the third phase, only one Baseline and the Concurrent schedules were used. Response-independent food delivery produced only a minimal amount of response suppression in this phase. Since the Conjoint conditions served as a control to analyze the source of the suppression effects, this condition was omitted because the expected suppression effects were not strong.

RESULTS

Figure 1 shows response rates across conditions of Phase 1, when the superimposed schedules were in effect for the whole session.

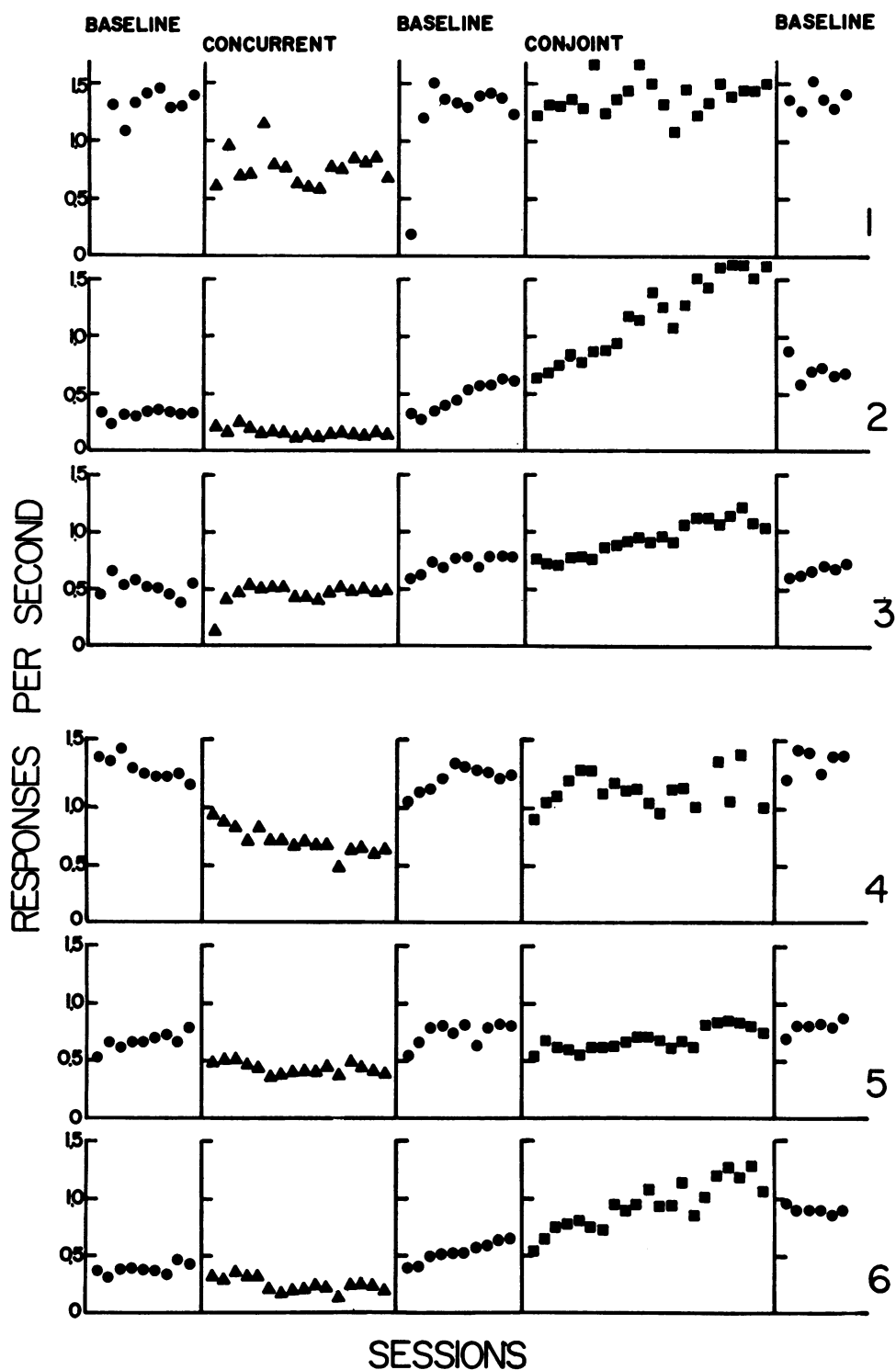


Fig. 1. Response rates across sessions when different conditions were in effect for the whole session (Phase 1): Baseline; Concurrent; Baseline; Conjoint; Baseline. The concurrent and conjoint schedules differed for Rats 1 to 3 and Rats 4 to 6 regarding the fixed or variable delivery of reinforcers. See text for additional details. Only the last nine sessions are shown for the first condition (eight for Rat 1 due to a recording failure).

Responses per second were calculated by dividing the number of responses per session by total session time.

The major finding is that response-independent food (the concurrent schedules) lowered response rates. Rat 1, for example, emitted rates of 1.4 responses per second under Baseline (VI 60-sec) conditions; rate lowered to 0.8 responses per second under the Concurrent condition. For Rat 2, the change in rate from the first Baseline condition to the Concurrent is not so obvious, since Baseline rates were low. However, suppression did occur: response rate approximated 0.3 responses per second under the Baseline and lowered to approximately 0.15 responses per second under the Concurrent condition.

Under the Conjoint conditions, Rats 2, 3, and 6 showed an increase in response rates. A minor problem with the results was the occasional change in rates from Baseline to Baseline. Rats 1, 4, and 5 were consistent, but Rats 2, 3, and 6 showed an increase in second and third baselines. Although the Baseline rate changed in some cases, these rates were higher in every case except one (Rat 3) when compared with rates under the concurrent schedules.

Figure 2 shows daily performance under Phase 2 when stimulus-correlated 60-sec components were presented with response-independent or response-dependent food. Figure 2 shows relative response rate, which was calculated by the formula:

$$\frac{Ra/Ta}{Ra/Ta + Rb/Tb},$$

where Ra and Ta stand for responses and time in the houselight-tone component in which response-independent or dependent food were delivered; Rb and Tb stand for responses and time in the lever-light component in which the VI 60-sec schedule operated. The measure is like suppression-ratio measures. If response rates in both components are equal, then the measure equals 0.5; if response rate in the 60-sec houselight-tone component is lower (higher) than in the lever-light component, the measure falls below (above) 0.5.

Figure 2 shows that the relative response rate approximated 0.5 under the Baseline conditions; thus, response rates tended to be equal in both components. When response-

independent food was presented, the measures dropped below 0.5 for five of the six subjects, indicating that response rates were lower in the component where response-independent food was delivered. Under the control (Conjoint) condition where extra food was delivered on a response-dependent basis, the measures approximated 0.5, indicating equal response rates in both components. The results are consistent with those of Figure 1, showing that response-independent delivery of food suppressed responding.

Figures 1 and 2 presented daily response measures for Phases 1 and 2; the data are representative of the daily performance observed in the other phases and are comparable with regard to the variability of performance across sessions. Accordingly, Figures 3, 4, and 5 show only summary data for the five experimental phases. The data in these figures are medians of the last five sessions under each condition. Although medians were used, use of means would show very similar results.

Figure 3 shows relative response-rate data for the five experimental phases. The data generally were calculated in the same way as those shown in Figure 2. The one exception was the first phase, where a multiple schedule was not used. To obtain relative response-rate measures in the first phase, separate comparisons were made between Concurrent rates and each of the three median baseline rates. Sets of three points are presented for this phase, one for each of the separate calculations.

The finding of most importance in Figure 3 is that response-independent food lowered relative response rate below 0.5. Response suppression occurred whether the response-independent food schedule operated for the whole session, for 60-sec periods, or for 10-sec periods; and suppression occurred whether the response-independent reinforcer was one pellet or five pellets. There were no obvious differences between the performance of Rats 1 to 3 and that of Rats 4 to 6; thus, it appears that the use of a fixed-time or variable-time schedule made little difference. Two findings will be discussed in detail below but deserve mention at this point. First, the degree of suppression was greater under five-pellet than comparable one-pellet conditions. Second, the one phase where suppression effects were inconsistent or minimal was the

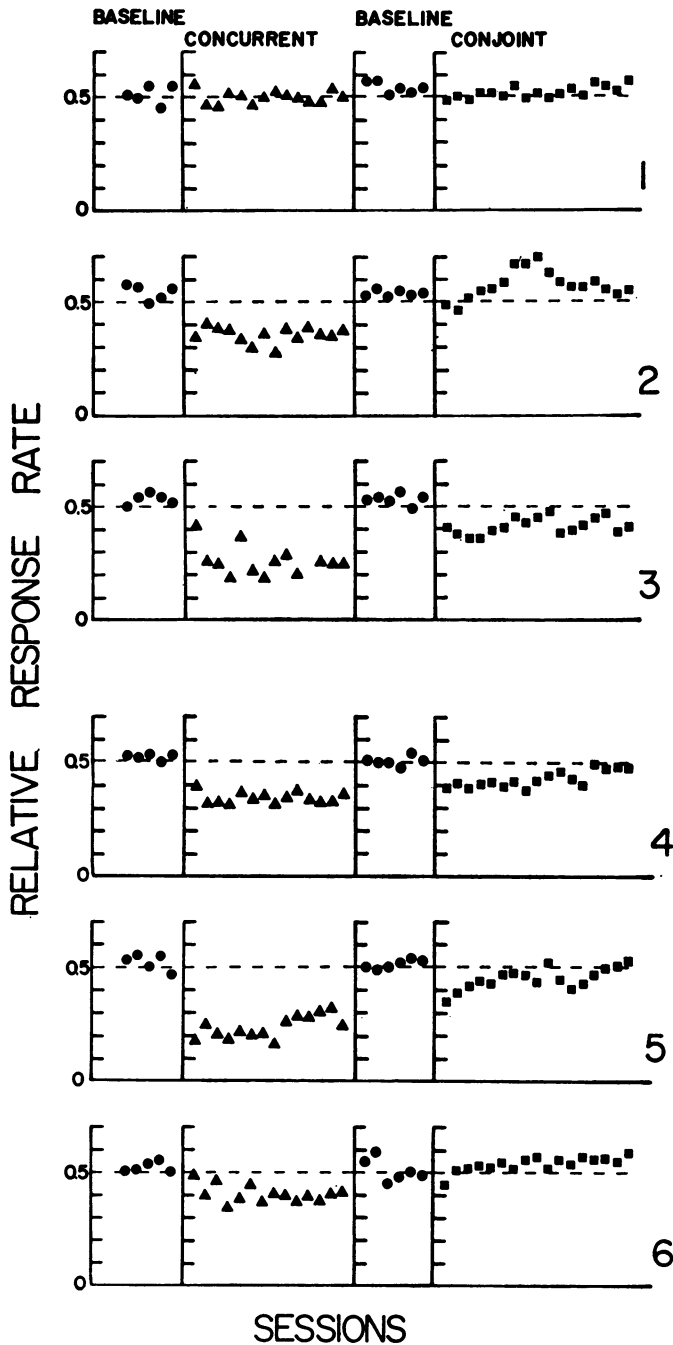


Fig. 2. Relative response rates across sessions for conditions in which the houselight-tone component operated for 60-sec periods (Phase 2): Baseline; Concurrent; Baseline, Conjoint. Concurrent and conjoint schedules differed for Rats 1 to 3 and Rats 4 to 6 regarding the fixed or variable delivery of reinforcers. See text for additional details. Only the last five sessions are presented for the first condition.

third phase, in which the response-independent schedule was in effect for 10 sec and the reinforcer was one pellet. Only four rats showed suppression under this condition,

and for two of these four the effects were very slight.

In addition to data on response-independent food, Figure 3 shows performance under

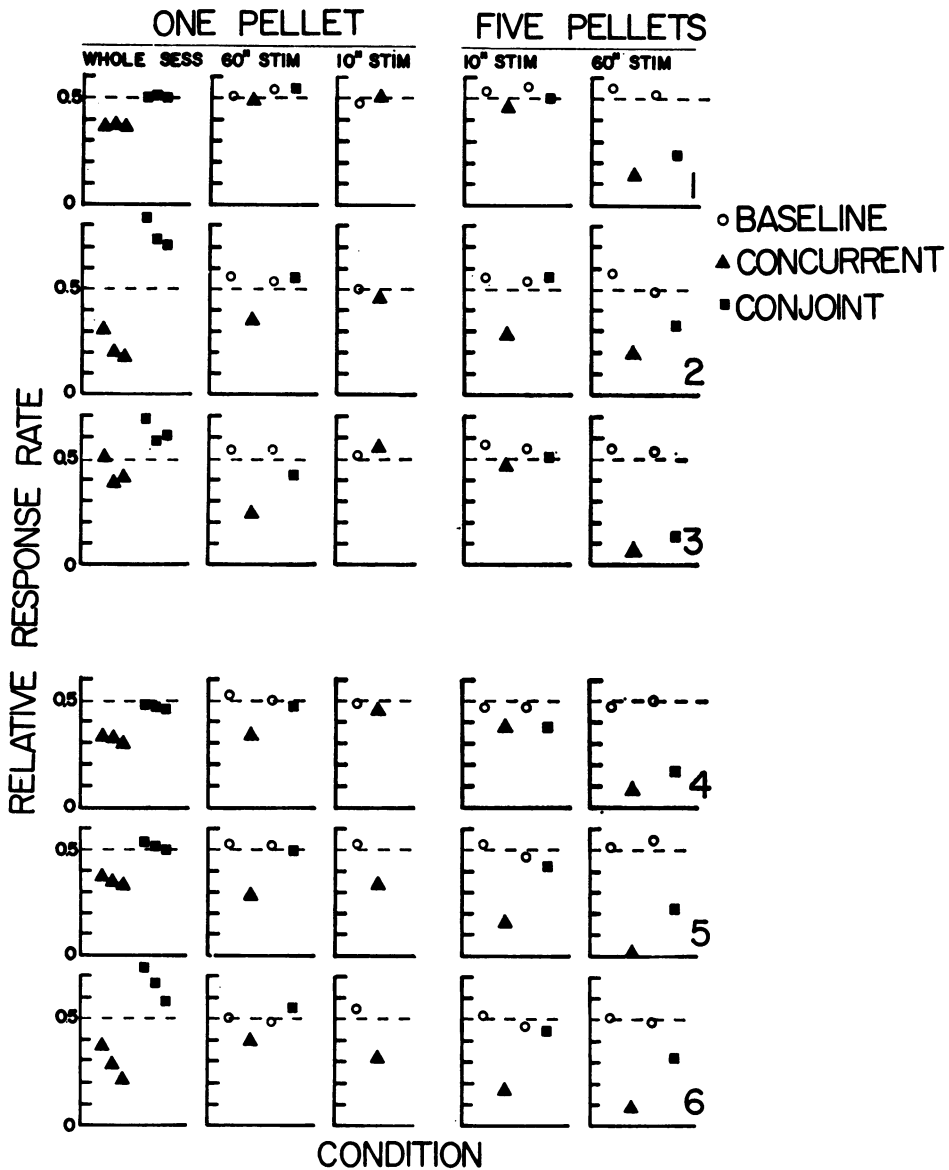


Fig. 3. Relative response-rate data for all experimental conditions: when extra food was response-independent (triangles) or response-dependent (squares); when concurrent and conjoint schedules operated for the whole session, for 60-sec periods, or for 10-sec periods; and when one pellet or five pellets were delivered.

Baseline and Conjoint conditions. Baseline performance, represented by the open circles, was characterized by relative response rates that approximated 0.5; response rates were equal in both components in those conditions where only the VI 60-sec schedule operated. Relative response rates under Conjoint conditions, shown by the squares, approximated 0.5 when one pellet was delivered, showing that response-dependent presentation of these extra reinforcers did not suppress perform-

ance. Under the five-pellet conditions, however, the results are more complex and there were cases where relative response rates did fall below 0.5. Under five-pellet conditions, Rats 1 to 3 did not show suppression when the houselight-tone component was in effect for 10 sec, but Rats 4 to 6 did, and all six rats showed suppression when the component lasted 60 sec. This pattern of results suggests that the delivery of five pellets every 10 sec may have suppressed responding in part due

to time spent consuming these pellets. Even the exceptions (Rats 1 to 3 with the 10-sec stimulus) support such a view. Rats 1 to 3 (FI 10-sec) produced the five pellets at the very end of the component; as a result, time spent eating five pellets would not interfere with responding in the houselight-tone component. For Rats 4 to 6, the five pellets were produced according to a variable-interval schedule and, as a result, eating could interfere with performance.

The results of the control conditions suggest that part of the suppression effect under five-pellet conditions may have resulted from the large amount of food. There was, however, a greater degree of suppression under concurrent conditions (comparison of triangles and squares in Phases 4 and 5). This finding demonstrates that response-independent food had a greater suppressive effect than did the extra response-dependent food; further, this finding indicates that the suppression obtained under Concurrent conditions was not solely the result of time spent eating.

Figure 3 showed that concurrent scheduling of response-independent food suppressed responding. Figure 4 highlights this effect by showing just the relative response-rate data from Concurrent conditions. Figure 4 provides a comparison of response-independent food effects in the different phases. The data for the six rats were averaged; the averaged functions were representative of the results of the individual rats (Figure 3).

Consider first the filled symbols. These symbols represent the averages of the data from Figure 3. Under one-pellet conditions, the degree of suppression was greatest when the response-independent schedule operated for the whole session, intermediate when it operated for 60-sec periods, and least when it operated for 10-sec periods. Under five-pellet conditions, there was a greater degree of suppression with 60-sec periods than with 10-sec periods. It appears that the longer the period of response-independent food, the greater was the degree of response suppression. Figure 4 also shows a greater degree of response suppression with five pellets than one pellet.

Delivery of five pellets produced suppression under Concurrent and Conjoint conditions (Figure 3). Accordingly, new calculations

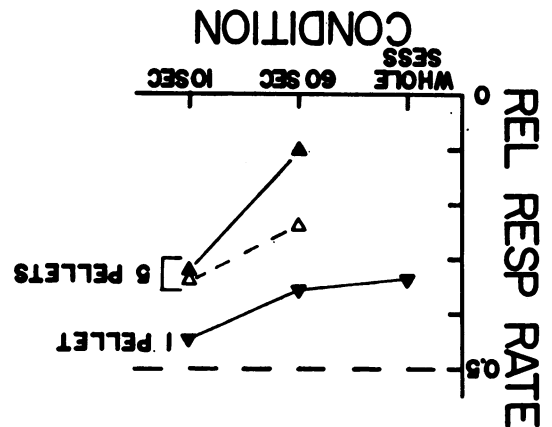


Fig. 4. Relative response rates, averaging the data for the six rats, showing the effects of response-independent food in the different experimental phases: when response-independent food was delivered for the whole session, for 60-sec periods, and for 10-sec periods. Filled symbols show performance separately when the response-independent reinforcer was one pellet or five pellets; the data are averages of the individual data presented in Figure 4. The unfilled symbols provide information using a measure "corrected" for suppression effects under control conditions (see text for additional details).

were made to take this result into account: relative response-rate calculations were made using response-rate data in the houselight-tone component under Concurrent and Conjoint conditions. Rat 1, for example, had rates of three responses per minute in this component under the Concurrent condition and 7.2 responses per minute under the Conjoint when the 60-sec component was used. There was suppression under both conditions when these rates were compared to rates in the lever-light component, but response rate was lower under the Concurrent condition than under the Conjoint. Relative response-rate calculations that compare concurrent and conjoint performance would produce a relative response rate of 0.29 for Rat 1 [$3/(3 + 7.2)$]. This type of calculation provides a comparison of the degree of suppression under concurrent conditions relative to that obtained under conjoint.

The unfilled symbols in Figure 4 show the degree of suppression with these "corrected" calculations under the five-pellet conditions. Even with Conjoint suppression taken into account, there was a greater degree of suppression under five-pellet conditions than under one-pellet conditions.

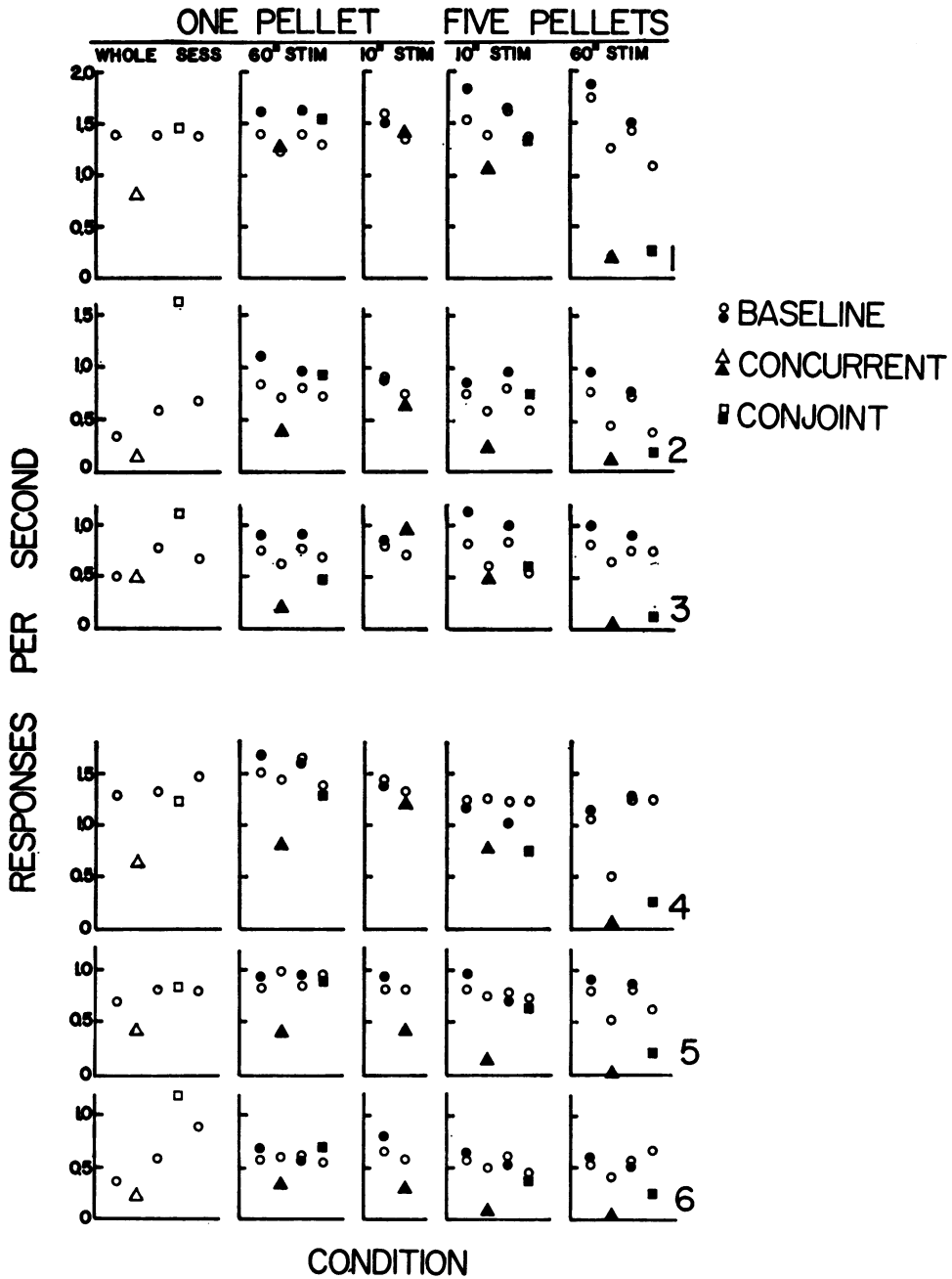


Fig. 5. Response-rate data for all experimental conditions: when extra food was response-independent (triangles) or response-dependent (squares); when concurrent and conjoint schedules operated for the whole session, for 60-sec periods, or 10-sec periods; and when one pellet or five pellets were delivered. Filled symbols show performance in the houselight-tone component and open symbols show performance in the alternate component.

Figure 5 is comparable to Figure 3 in showing data for all phases, but Figure 5 shows absolute response rates in the lever-light and houselight-tone components.

In many ways, Figure 5 complements Figure

3. Figure 3 showed that relative response rates fell below 0.5 under Concurrent conditions; Figure 5 shows that absolute response rates were below baseline rates under Concurrent conditions. A comparison of the triangles

(concurrent schedules performance) and circles (baseline performance) shows that the triangles were below the circles across all phases with only three exceptions (two for Rat 1 and one for Rat 3). Figure 3 showed that relative response rates approximated 0.5 when only the Baseline VI 60-sec schedule operated. A comparison of filled and comparable unfilled circles in Figure 5 shows that absolute response rates tended to be the same in these conditions. Figure 3 showed that relative response rates approximated 0.5 under Conjoint conditions where one pellet was delivered, but fell below 0.5 when five pellets were delivered. A comparison of squares and comparable unfilled circles in Figure 5 shows that conjoint schedule rates approximated baseline rates when one pellet was delivered but were lower than baseline rates when five pellets were delivered.

Figure 5 provides information not contained in Figure 3. Response rates tended to be roughly constant in the lever-light (VI 60-sec) component throughout the experiment (see and compare open circles). Although rates in this component were roughly the same, there were small but consistent changes in the different conditions of the multiple-schedule phases. A comparison of the open circles in these phases reveals that response rates were higher in the first and third conditions than in the second and fourth conditions; there was a pattern for rates to be high-low-high-low across the four conditions. First and third conditions were Baseline while second and fourth were Concurrent and Conjoint. The performance in the lever-light component (open circles) was affected by the schedule in the alternate component; concurrent and conjoint schedules in the houselight-tone component led to lower rates in the lever-light component than did the baseline VI 60-sec schedule. This does not appear to be an induction effect, where rates were lowered in the lever-light component due to the lowered response rates in the concurrent or conjoint schedule components. Response rates increased above baseline in the conjoint component of Phase 2 for Rats 1, 2, and 6, but response rates still declined in the lever-light component. Thus, the lowering of response rate in the lever-light component seems to be independent of response rate in the alternate, concurrent, or conjoint schedule component.

The lowering of response rate may, however, be a contrast effect due to the increased reinforcement rate in the concurrent and conjoint schedule components (Rachlin 1973).

DISCUSSION

The major finding of our study is that response-independent food suppressed response rate. Response suppression resulted whether response-independent food was in effect for the entire session or during components of a multiple schedule. The results are compatible with research involving concurrent and multiple schedules. Further, the results raise questions about the typical explanations of positive conditioned suppression phenomena in terms of operant-responder interactions. Each of these aspects of the results will be discussed in turn.

The results are compatible with research on concurrent schedules. Under concurrent schedules in which two schedules operate simultaneously, each for a separate response, each response is affected not only by reinforcement for that response but also by reinforcement for the alternate response. Response rate increases as reinforcement rate for that response increases, but response rate decreases as reinforcement rate for the alternate response increases (Catania 1963, 1966). Closer to the present experiment is the research of Rachlin and Baum (1972), who demonstrated that response rate declined when response-independent food was concurrently presented. Our study contains elements of the concurrent situation like that used by Rachlin and Baum. When response-independent food was scheduled for the entire session, the procedure, results, and analysis were the same as those of Rachlin and Baum. When response-independent food was presented during 60-sec and 10-sec multiple-schedule components, the concurrent schedule was in effect for only part of the session. Response suppression still resulted, demonstrating that suppression by concurrently presented response-independent food obtains in multiple-schedule procedures as well as in simple concurrent schedules. Additionally, our findings of a greater degree of suppression under five-pellet conditions than under one-pellet conditions agree with those of Rachlin and Baum: they observed a greater degree of response suppres-

sion with greater amounts of response-independent food.

In addition to the general suppressive effects of response-independent food, concurrent delivery of response-independent food in one component of a multiple schedule produced behavioral contrast effects like those observed in other multiple schedules. Behavioral contrast occurs in multiple schedules when reinforcement rates differ in the two components (*e.g.*, Rachlin, 1973). Two types have been demonstrated: positive contrast and negative contrast. Positive contrast involves an increase in response rate in one multiple-schedule component that can result when reinforcement rate is reduced in the alternate component. Negative contrast involves a decrease in response rate in a component that results when reinforcement rate is increased in the alternate component.

The results shown in Figure 5 suggest negative contrast. Under the multiple schedules, a variable-interval schedule operated in both components for the Baseline conditions; as a result, the reinforcement rate was the same in both components. When, however, concurrent or conjoint schedules operated in the houselight-tone component, there was a higher rate of food presentation in that component. The arrangement is like the traditional negative contrast procedure where an increase in reinforcement rate in one (houselight-tone) component lowers response rate in the alternate component. The results in Figure 5 show that response rates declined in the lever-light variable-interval component when extra food was delivered in the alternate, houselight-tone component (*i.e.*, comparison of open circles under Baseline conditions with those under Concurrent and Conjoint conditions). The negative contrast effects appear to result from the higher reinforcement rate in the houselight-tone component and not from other factors. Contrast effects were observed whether the extra reinforcers were response-dependent or response-independent, and whether response rates were relatively high or low in the houselight-tone component.

Our results showed different degrees of response suppression when response-independent food was scheduled for the whole session, for 60-sec periods, or for 10-sec periods (Figure 4); these results are consistent with those obtained in other experiments on con-

trast. The literature indicates that contrast effects depend on the alternation of schedule components that provide different rates or amounts of reinforcement. Alternation of a component with a second (having a lower reinforcement rate) may increase response rate above that observed if the schedule operated in isolation. A particular schedule (*e.g.*, VI 15-sec), for example, would be expected to generate a higher response rate if that schedule alternated with a second schedule (*e.g.*, VI 120-sec) in a multiple-schedule procedure than it would if the schedule simply operated in isolation. Our results are consistent, in that the degree of response suppression was not as great under multiple-schedule conditions as under conditions where response-independent food was delivered during the entire session. One effect of response-independent food was to suppress responding across conditions. But, at the same time, the multiple-schedule conditions provide a higher reinforcement rate in the houselight-tone component. Alternation of the lever-light component (low reinforcement rate) and the houselight-tone component (higher reinforcement rate) appears to have enhanced responding in the houselight-tone component that retarded the degree of response suppression in the multiple-schedule conditions (Rachlin, 1973). Comparison of whole-session and multiple-schedule conditions thus suggest that these were two more-or-less opposing effects under multiple-schedule conditions: first, inhibiting effects of response-independent food that suppress responding; second, contrast effects due to the alternation of components that tend to enhance responding.

The results of less suppression when the houselight-tone component was 10 sec than 60 sec also are consistent with the results of contrast experiments. Several experiments have demonstrated a different degree of contrast depending on the duration of the components; larger contrast effects have been observed the shorter the duration of the component (Green and Rachlin, 1975; Killeen, 1972; Shimp and Wheatley, 1971; Todorov, 1972). Our findings of less suppression with the 10-sec component are consistent in that conditions that maximize contrast (short components) would counteract the suppressive effects of response-independent food to a greater degree.

Our experiment used rats as subjects and obtained response suppression, a common finding when rats (and monkeys) are used as subjects. In one sense, the results are different from those observed when pigeons are subjects and their key peck is the response. However, the results suggest certain similarities when considering the data obtained from pigeons pecking keys and rats pressing levers.

The positive conditioned suppression procedure typically produces response suppression when rats press levers. However, this same procedure often enhances responding in experiments in which pigeons peck keys: when extra response-independent food is delivered in one component (CS component) key-peck rate is higher in that component than in an alternate, baseline component (e.g., LoLordo, McMillan, and Reiley, 1974; Schwartz, 1976). The enhancement appears to depend on the use of the key-peck response and the use of a visual stimulus. If treadle pressing replaces key pecking, or an auditory stimulus replaces the visual stimulus, suppression rather than enhancement is obtained (LoLordo *et al.*, 1974). The seemingly different results are consistent with explanations in terms of the degree to which autoshaping and contrast phenomena affect performance (see Hearst and Jenkins, 1974; Schwartz and Gamzu, 1977, for general reviews and discussions). Strong autoshaping and contrast effects have been reported when pigeons serve as subjects and key pecks are the responses; minor (or negligible) effects have been reported when rats and monkeys are subjects, when lever or treadle presses are the responses, and when auditory stimuli are used with pigeons. The response enhancement observed in pigeon experiments like the present has been interpreted as the result of strong contrast and autoshaping effects. Response suppression in rat experiments has been interpreted as the result of a lack of strong contrast and autoshaping effects (e.g., Schwartz and Gamzu, 1977).

An interpretation of the data in terms of contrast and autoshaping makes sense and is not at issue here. However, our data suggest a change in the way we consider some of the data. Previous discussions have, in a sense, focused on the differences obtained in pigeon and rat experiments, enhancement *versus* suppression. One reason may be that previous

experiments have emphasized the comparison of responding in a "CS" component with that in an alternate baseline component; such comparisons show higher rates for pigeons (enhancement) and lower rates for rats (suppression). In contrast, the present discussion has emphasized a different comparison, one of performance under whole-session and multiple-schedule conditions. This comparison focuses on a similarity in the behavior of pigeons and rats. This comparison shows that response suppression results when response-independent reinforcers are delivered to pigeons (Rachlin and Baum, 1972) or rats (present study), providing that these reinforcers are scheduled throughout the entire session. When, however, response-independent reinforcers occur only intermittently during multiple-schedule components, contrast effects act to offset the effects of response-independent food. With pigeons, for which contrast effects are quite strong, the inhibiting effects of response-independent food are offset to such a degree that the end result is response enhancement. With rats, contrast effects are not as strong, with the end result that the multiple-schedule procedure only retards the degree of response suppression. The data for both rats and pigeons appear similar, in that multiple-schedule procedures seem to produce less suppression than comparable whole-session procedures.

The present experiment raises questions about traditional interpretations that relate positive conditioned suppression phenomena to operant-respondent interactions. According to these interpretations, suppression results from the CS-US pairing of a stimulus with a response-independent reinforcer. Our data indicate that suppression was a function simply of the concurrent scheduling of response-independent reinforcers, and that a CS-US pairing arrangement was not necessary. Suppression resulted whether a CS-US pairing arrangement was used (multiple-schedule conditions) or not used (whole-session conditions). One possibility we considered was that there might be multiple sources of suppression, one source related to the response-independent presentation of food, and the other to operant-respondent interactions. Perhaps the 10-sec component might function as an optimum CS that produced additional suppression beyond that observed in the other conditions. The data

do not support this possibility. A greater degree of suppression was not observed with the 10-sec components; the greatest amount of suppression occurred under the whole-session conditions and least under the 10-sec conditions.

Although our findings suggest that operant-respondent interactions did not contribute to response suppression, these results do not mean that there were no interactions of this type. The multiple-schedule conditions did arrange stimulus-reinforcer pairings that would facilitate operant-respondent interactions. The results of less suppression under multiple-schedule conditions suggest that such interactions may have affected performance: the smaller degree of suppression may indicate an enhancing effect of the stimulus-reinforcer pairings. This aspect of the results has been discussed above in the context of behavioral contrast. Other authors have pointed out and provided evidence that behavioral contrast may be closely related to operant-respondent interactions (e.g., Rachlin, 1973; Schwartz and Gamzu, 1977). So, it is possible that there were operant-respondent interactions, if not those usually proposed with regard to positive conditioned suppression.

REFERENCES

- Azrin, N. H. and Hake, D. F. Positive conditioned suppression: conditioned suppression using positive reinforcers as the unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 167-172.
- Blackman, D. E. Conditioned anxiety and operant behavior. In R. M. Gilbert and J. D. Keehn (Eds), *Schedule effects: drugs, drinking, and aggression*. Toronto: University of Toronto Press 1972. Pp. 26-49.
- Blackman, D. Conditioned suppression and the effects of classical conditioning on operant behavior. In W. K. Honig and J. E. R. Staddon (Eds), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1977. Pp. 340-363.
- Catania, A. C. Concurrent performances: reinforcement interaction and response independence. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 253-263.
- Catania, A. C. Concurrent operants. In W. K. Honig (Ed), *Operant behavior: areas of research and application*. New York: Appleton-Century Crofts, 1966. Pp. 213-270.
- Catania, A. C. Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 517-526.
- Catania, A. C., Deegan, J. F., and Cook, L. Concurrent fixed-ratio and avoidance responding in the squirrel monkey. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 277-281.
- Catania, A. C. and Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 327-383.
- deVilliers, P. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon (Eds), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1977. Pp. 233-287.
- Edwards, D. DeA., Peek, V., and Wolf, F. Independently delivered food decelerates fixed-ratio rates. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 301-307.
- Green, L. and Rachlin, H. Economic and biological influences on pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1975, **23**, 55-62.
- Hake, D. F. and Powell, J. Positive reinforcement and suppression from the same occurrence of the unconditioned stimulus in a positive conditioned suppression procedure. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 247-257.
- Hearst, E. and Jenkins, H. M. *Sign tracking: the stimulus-reinforcer relation and directed action*. Psychonomic Society Monograph, 1974.
- Kelly, D. D. Suppression of random-ratio and acceleration of temporally spaced responding by the same prereward stimulus in monkeys. *Journal of the Experimental Analysis of Behavior*, 1973, **20**, 363-373.
- Killeen, P. A yoked-chamber comparison of concurrent and multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1972, **18**, 13-22.
- LoLordo, V. M., McMillan, J. C., and Riley, A. L. The effects upon food-reinforced pecking and treadle-pressing of auditory and visual signals for response-independent food. *Learning and Motivation*, 1974, **5**, 24-41.
- Lyon, D. O. Conditioned suppression: operant variables and aversive control. *Psychological Record*, 1968, **18**, 317-338.
- Meltzer, D. and Brahlek, J. A. Conditioned suppression and conditioned enhancement with the same positive UCS: an effect of CS duration. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 67-73.
- Miczek, K. A. and Grossman, S. P. Positive conditioned suppression: effects of CS duration. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 243-247.
- Millenson, J. R. and deVilliers, P. A. Motivational properties of conditioned anxiety. In R. H. Gilbert and J. R. Millenson (Eds), *Reinforcement: behavioral analyses*. New York: Academic Press, 1972. Pp. 97-128.
- Rachlin, H. Contrast and matching. *Psychological Review*, 1973, **80**, 217-234.
- Rachlin, H. and Baum, W. M. Effects of alternative reinforcement: does the source matter? *Journal of the Experimental Analysis of Behavior*, 1972, **18**, 231-241.
- Rescorla, R. R. and Solomon, R. L. Two process learning theory: relationships between Pavlovian conditioning and instrumental learning. *Psychological Review*, 1967, **74**, 151-182.

- Schwartz, B. Positive and negative conditioned suppression in the pigeon: effects of locus and modality of the CS. *Learning and Motivation*, 1976, 7, 86-100.
- Schwartz, B. and Gamzu, E. Pavlovian control of operant behavior: an analysis of autoshaping and its implications for operant conditioning. In W. K. Honig and J. E. R. Staddon (Eds), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1977. Pp. 53-97.
- Shimp, C. P. and Wheatley, W. L. Matching to relative reinforcement frequency in multiple schedules with a short component duration. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 205-210.
- Smith, J. B. Effects of response rate, reinforcement frequency, and the duration of a stimulus preceding response-independent food. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 215-221.
- Todorov, J. C. Component duration and relative response rate in multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 45-50.
- Van Dyne, G. C. Conditioned suppression with a positive US in the rat. *Journal of Comparative and Physiological Psychology*, 1971, 77, 131-135.
- Zeiler, M. D. Fixed and variable schedules of response-independent reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 405-414.
- Zeiler, M. D. Positive reinforcement and the elimination of reinforced responses. *Journal of the Experimental Analysis of Behavior*, 1976, 26, 37-44.

Received 3 November 1976.

(Final acceptance 5 July 1978.)